REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(LEAVE BLANK)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1998	Professional Paper

4. TITLE AND SUBTITLE
Flight Test Automation Options

5. FUNDING NUMBERS

6. AUTHOR(S)
Dean Carico

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Air Warfare Center Aircraft Division
22347 Cedar Point Road, Unit #6
Patuxent River, Maryland 20670-1161

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Flight Test Automation Options

Dean Carico
Test and Evaluation Engineering 4.11.3.2
Naval Air Warfare Center Aircraft Division
Patuxent River MD 20670
Phone: (301) 342-1382

Abstract

Flight testing is often called the key component of test and evaluation. The cost of conventional flight testing is expected to escalate approaching the 21st century and beyond. Augustine noted several years ago that if this trend continues, a single advanced fighter aircraft would cost more than the entire DoD budget by the middle of next century. As the cost of flight testing continues to escalate in a predicted hostile fiscal environment, it is important to consider options to help minimize flight test cost. Suggestions range from completely eliminating developmental testing to employing a variety of flight test automation options. Flight test automation option concepts range from the fantasy of "push a button, the test is done," to the more practical use of a personal computer to help with some repetitive flight test tasks and to help store large amounts of related data. Options to help automate specific aspects of flight testing are starting to gain acceptance. Several test automation options exist that have the potential to enhance flight testing by permitting it to be done better, faster, cheaper, and safer. This paper briefly discusses a variety of flight test automation options including the OSD Automated Test Planning System (ATPS) work to automate the test and evaluation master plan (TEMP), the Army Test and Evaluation Planning and Reporting System (TEPRS), the G&C System work on Test_Plan, the Calspan/Air Force Test Planning, Analysis, and Evaluation System (PAES) program, the Boeing Planning and Reporting Organizer For Test Engineers (PROFITE) program, and the Naval Air Warfare Center Aircraft Division Automated Flight Test Engineering System (AFTES) program and high performance computing program on flight test automation.

Background

Powered aircraft flight testing has been ongoing for almost a century, but new lessons still appear to be learned for each new flight test program. At the start of the 20th century, aircraft entrepreneurs were jacks of all trades, who designed the aircraft, built the aircraft and performed the flight testing. At this stage, the flight test procedures and flight test requirements were being developed. As the aircraft became more complex, specialized flight test crews were required, along with specialized test and data analysis techniques.

In 1943, many Navy activities were consolidated at Patuxent River, Md., to form the Naval Air Test Center (NATC) (currently the Naval Air Warfare Center Aircraft Division (NAWCAD)). Initial work toward standardizing test techniques and test requirements began with the establishment of the US Navy Test Pilot School (USNTPS), which supported NATC test directorates. Navy rotorcraft testing in the late 1960's was performed using techniques defined in the Rotary Wing Branch Test Manual (1959) and USNTPS test manuals. Data reduction, at this time, was accomplished using a adding machine plus a desktop calculator which could be programmed with up to 15 steps. This was a big step forward for new engineers who had just got

through college using slide rules. Hand calculators and desk top calculators were used for data reduction during the 1980's. A preliminary test report and test plan database was developed during this time frame by the Rotary Wing Sea Control Department. Personal computers showed up at the Rotary Wing Aircraft Test Directorate in the 1980's, and during this timeframe a survey indicated that it could take up to a month to develop a comprehensive rotorcraft flying qualities and performance test plan. With the personal computer, it was possible to take an approved test plan and change the helicopter using a search and replace function of the word processor software. Data reduction techniques could be programmed in general terms and could be used for different test programs. New engineers and pilots were continually entering the system, and developing methodologies to capture the knowledge of the "test experts" before they retired or changed jobs was considered important. Thus, flight test automation options have been evolving since the turn of the 20th century. If the DoD defense budget had continued to increase after the cold war with more new aircraft being tested and procured each year, there would have been little incentive to radically change the way flight testing had been traditionally performed.

Introduction

Current factors such as declining budgets, reduced staffs, increased project cost, and tightened delivery schedules all point to the need to improve the current flight test process. The cost associated with the next generation rotorcraft testing, training, and support, using current techniques, promises to escalate in a predicted hostile fiscal environment. Vision 21 [1] calls for a reduction in the current test and evaluation (T&E) infrastructure. The Simulation, Test and Evaluation Process (STEP) [2] and DoD Regulation 5000.2-R [3] require modeling and simulation throughout the system life cycle. Zittel [4] reviews the DoD Simulation Support Plan which calls for "... increasing emphasis on the use of modeling and simulation (M&S) in our acquisition programs to reduce cost and schedule without sacrificing quality or performance." Simulation based acquisition is considered an effective, affordable mechanism for fielding complex technologies and may help to make DoD a "smart buyer" [5]. Programs associated with some form of flight test automation have been ongoing for some time.

Automation Systems

Automated Test Planning System (ATPS) - This program was sponsored by the Deputy Director, Systems Engineering and Evaluation (Test and Evaluation) in the Office of Under Secretary of Defense for Acquisition and Technology at OSD. The program focus includes using expert system based tools to assist in reviewing or drafting a Test and Evaluation Master Plan (TEMP) and in assessing Test & Evaluation (T&E) program risk. This SAIC program [6] called Automated Test Planning System (ATPS) involves a joint approach to enhance and standardize TEMP development and review. ATPS includes the following modules:

TEMP Build Module
TEMP Review Module
Test and Evaluation Program Risk Assessment Module
Test and Evaluation Program Design Module

The ATPS program contains the DoD 5000 series documents to support T&E and acquisition programs, as shown in figure 1. The software is available for both PC and Macintosh computers and can be downloaded from the World Wide Web. The program requires approximately 4 MB of storage and 8 MB of RAM. The ATPS program has over 600 registered users supporting multi-service programs. The ATPS has been used successfully on the F-22 program.

Test and Evaluation Planning and Reporting System (TEPRS) - This program, originally known as the Test and Evaluation Plan (TEP) Builder, was developed by the Army Test and Evaluation Command, PRC Inc., and the University of Michigan to support Army operational test and evaluation (OT&E). The TEP Builder includes several different programs, including the knowledge base and tool set. The TEP was designed primarily for new testers with strong service-related expertise, but little familiarity with the OT&E process [7]. The program is currently designated TEPRS, and focuses on T&E planning and reporting. A functional block diagram of TEPRS is presented in figure 2. The TEPRS primary functions include:

Create definitions for systems test and evaluation
Manage definition consistency across all test documents
Provide commercial-of-the-self (COTS) software integration

The TERPS program is designed to operate on a personal computer running Windows software. The program requires 6MB of hard drive space for installation, and includes a run time version of Microsoft Access. TERPS is undergoing Beta testing and future versions will include such features as spreadsheet test matrix design options, presentation options, a repository of test factors, system evaluation report type documents, test design and analysis options, and data element dictionaries.

TEST_PLAN - This software package for workstation computers is developed by G&C Systems, Inc., to help flight test engineers (FTE) plan and track flight test programs by mapping requirements to test points, flight test maneuvers, and flights [8]. TEST_PLAN is designed to reduce the cost of flight testing by maximizing the productive use of available flight time, minimizing planning and scheduling errors, providing management visibility into program status.

TEST_PLAN was initially demonstrated in 1989, and has been commercially available for five years. It was used at Saab Scania on the JAS-39 and Saab 2000 flight test programs, and at the NASA Dryden Flight Research Facility, Edwards Air Force Base (AFB) on F-18 research projects. In addition, the Air Force Flight Test Center (AFFTC), Edwards AFB, the C-17 Combined Test Force and the C-130 Combined Test Force at AFFTC are using TEST_PLAN. The Boeing/Lockheed/General Dynamics F-22 Team has also purchased TEST_PLAN for the F-22 flight test program. Hindustan Aeronautics Limited is using TEST_PLAN on their Light Combat Aircraft (LCA) flight test program.

TEST_PLAN is a large software package with extensive graphics and must be hosted on high-end graphics workstation computers running under UNIX or VMS for satisfactory performance. TEST_PLAN is integrated with ORACLE, a commercially available relational database management system. TEST_PLAN is currently being ported to PC computers running Windows

NT 4.0 or subsequent. This version should be released in mid 1998. TEST_PLAN is an evolving system. Current work is centered around providing better support for avionics system test planning and requirements tracking.

A diagram of the flight test planning functionality supported by TEST_PLAN is presented in Figure 3. TEST_PLAN automatically generates documentation (flight card decks, flight reports, instrumentation reports) in FrameMaker, Interleaf or Microsoft Word. TEST_PLAN contains a 3 DOF simulation facility capable of generating flight profiles for a given airplane and displaying them on digital maps. The system requires standard aerodynamic, propulsion and geometric data on the aircraft to be simulated.

Test Planning, Analysis, and Evaluation System (PAES) - Test PAES is a software package for personal computers developed by Calspan SRL Corporation for the US Air Force Armstrong Laboratory [9-12]. The program was initiated in 1992 with initial software delivery in 1993, and with field testing commencing in early 1994, and is described in ITEA Journal Vol 19, No. 1 of March/April 1998. The software consists of four components, as summarized in figure 4, and the program is currently located at over 50 test sites in the US.

Planning and Reporting Organizer For Test Engineers (PROFTE) - PROFTE is a Microsoft Access and Word based software package for personal computers developed by the Boeing Aerospace Group (formerly McDonnell Douglas) to support the F/A-18E/F flight test program [13]. The criteria for the software package included the ability to support over 20,000 test points, over 2000 flights, seven aircraft, six test sites, multi-users, and no budget outside normal test planning work. PROFTE was designed to help the test team members prepare test plan work descriptions, prepare flight cards, track test points, prepare flight reports, and report test program progress. Test personnel from the F-18A-D, AV-8B, F15A-E, T-45,YF23, and B-2 programs provided lessons learned and suggestions for PROFTE design and development. PROFTE has been used over the past three years to support over 1600 F/A-18E/F flights.

The primary PROFTE databases include a test point tracking system, flight card/reporting database, external loadout database, loadout scheduling database, and flutter control unit program management database, as shown in figure 5. The test point tracking system database is the heart of the system and it contains: test points, test point status, test point/aircraft assignments, test work description, test attempts, test attempt status, and flight time. The flight card/reporting database is used by test team members for test mission planning parameters and test mission reporting parameters. This database also provides aircraft metrics and flight logs. The external loadout database provides information on all external stores configurations. The loadout scheduling database is used to schedule aircraft loading and stores delivery and provide Navy flight schedule documentation. The flutter exciter control unit database is used to support flutter and parameter identification testing.

Automated Flight Test Engineering System (AFTES) - *T*his concept was initiated as a low-key, in-house Navy Patuxent River test plan development program in 1987 to use new software to support fixed-wing electro-optics testing. The program focus shifted to rotorcraft helicopter/ship and flying qualities and performance testing in FY89, and the concept was called

the Test Plan Automation System (TPAS). Different expert shell structures were evaluated and limited work was performed to input flight test knowledge base information into the TPAS system. Funding for this initial work ended in 1992, and in 1994 a small business innovative research (SBIR) program was initiated that renewed the effort. Stottler, Henke, and Associates, Inc. (SHAI), is prime on the SBIR and it focuses on using artificial intelligence technology to enhance rotorcraft test planning, test reporting, data analysis, and project management. This SBIR program project is called the Automated Flight Test Engineering System (AFTES). The AFTES concept is illustrated in figure 6, and should be available for use during FY98. Test team members can select up to nine different types of helicopter/ship or dynamic interface tests with a beta version of AFTES, and after answering a few questions, generate a comprehensive test plan in approximately 15 minutes using a Pentium PC. A second SBIR program focuses on developing a PC tutorial to support rotorcraft handling qualities, flight control system, and loads testing. Integrating the AFTES program with a variety of flight test analysis tools, as summarized in figure 7, forms one option for a rotorcraft flight test automation program.

High Performance Computing Flight Test Automation Program - The purpose of this program is to develop advanced simulation software that can be interfaced with high performance computing hardware to help automate aircraft/systems testing. This program provides a unified environment to support current and next generation aircraft/systems testing. The work involves integrating and enhancing advanced technology programs in simulation modeling and flight test automation to form a unified environment to enhance testing. Current rotorcraft simulation models are vehicle type specific and do not have the high fidelity rotor and fuselage components required to predict loads. The current modeling environment also does not support helicopter/ship operational envelope development due to limitations in current aircraft modeling and ship environment modeling. A physics-based generic structure simulation model, with selectable levels of fidelity, has the potential to support testing on a wide variety of multi-service rotorcraft. Elastic rotor blade and fuselage components, combined with complex ship airwake models, require high performance computing (HPC) hardware for potential real-time operations, as well as code parallelization, and code optimization using HPC hardware. Aircraft model code enhancements are required to better support flight testing and to take advantage of available HPC hardware. Code enhancements are required to better support basic flying qualities and performance testing, helicopter/ship dynamic interface testing, and reliability and maintainability testing. A variety of artificial intelligence (AI) technologies could be combined to help automate test planning, data analysis, and test reporting. The test plan contains a flight test matrix appendix which lists all the planned flights along with flight test conditions and data plot formats. Integrating the test plan automation program with a high fidelity simulation model on a high performance computing system would allow the test flights to be run analytically while the test plan was being generated. The HPC system could be used to support real-time test team training or numerous parameter sweeps at each data point using the complex aircraft model. This parameter sweep information could be used to provide quick answers to sponsor questions on "What happens if I change ..x.. or ..y.. on my aircraft?" The ability to do comprehensive flight test programs and design trade-off studies analytically has the potential of large savings for the test community. The capability has broad multi-service and commercial test applications, with initial focus on Army, Navy, and Air Force rotorcraft/systems testing. The generic nature

of the proposed software make it portable, scaleable, and reusable. It also satisfies the high priority DoD need to do testing better, faster, and cheaper, and to help reduce the overall test and evaluation infrastructure.

Summary

Flight testing is and will continue to remain a very interesting and challenging occupation for future generations. The test team knowledge base required for safe and effective flight testing continues to increase with increasing aircraft complexity. Declining budgets and test support personnel emphasize the importance of options to improve test program efficiency while retaining safe test procedures. Several flight test automation options exist, in various stages of development, testing, and application, which are designed to help test team members do more with limited resources available. These test automation programs have the potential to permit future flight testing to be done better, faster, cheaper, and safer.

Additional Information (program developer/contractor)
ATPS - Mr. Dave Duma, (703) 413-3137, david.w.duma@cpmx.saic.com
TEPRS - Mr. Paul Johnson, (703) 671-5656, johnsonp@optec.army.mil
TEST_PLAN - Mr. Marle Hewitt, (714) 248-7212, mdhjdh@ix.netcom.com
PAES - Dr. Valerie Gawron, (716) 631-6916, gawron@calspan.com
PROFTE - Mr. Michael Ludwig, (301) 757-4604, michael.f.ludwig@boeing.com
AFTES - Mr. Dick Stottler, (650) 655-7242, http://www.shai.com

References

[1] Sanders, Patricia, Consolidation & the Future of Flight Test Facilities, The ITEA Journal of Test and Evaluation. Volume 17, Number 3, September/October 1996

[2] Hines, Dennis and Norton, William, Simulation, Test, and Evaluation Process, ITEA Journal, Vol 18, No. 3, Sep/Oct 1997

[3] Jones, Edward, LT.COL. USA, Test & Evaluation Policy Changes in New DoD 5000 Series, Program Manager, Defense Systems Management College Press, Jul/Aug 1996

[4] Zittel, Randy, Longuemare Endorses Two Important Modeling and Simulation Documents, Program Manager, September-October 1997

[5] Sanders, Patricia, Simulation Based Acquisition, Program Manager, Sep/Oct 1997

[6] Roth, Scott, et. al., Automated Test Planning System, ITEA Journal, Volume 16, Number 1 of March/April 1995; Crosstalk, November 1994; and The Program Manager, September 1994

[7] Wyant, Kerry, et al, "Test and Evaluation Plan Builder," ITEA Journal, December 1995/January 1996

[8] TEST_PLAN Canody, Cheryl and Bender, Victor, The Evolution of an Automated Test Planning Tool, 1994

[9] Gawron, V.J., Joseph, T.C. and Jeziorowski, M.M.: "A PC-Based Test and Evaluation Tool," ITEA Journal, March/April 1998

[10] Gawron, V.J., Barickman, F., and Garrott, W.R: "Test Planning, Analysis, and Evaluation System (Test PAES): A Data Archiving Tool for Engineers and Scientists." Society of Automotive Engineers Paper 970453, Warrendale, PA., SAE, February 1997

[11] Gawron, V.J., Dennison, T.W., and Biferno, M.A.: "Mockups, Physical and Electronic Human Models, and Simulations." In T.G. O'Brien and S.G. Charlton (Ed.) Handbook of Human Factors Testing and Evaluation, Mahwah, New Jersey, Lawrence Erlbaum Associates, 1996

[12] Gawron, V.J., Charlton, S., Turner, A., and Purvis, B.: "An Integrated Tool Set for Crewstation Test and Evaluation," Journal Of Air Force Operational Test and Evaluation, 27-32, July 1996

[13] Ludwig, Michael, An Affordable Planning and Reporting Organizer for Test Engineers (PROFTE), SFTE 28th Annual Symposium, Orlando, FL, August 18-22, 1997

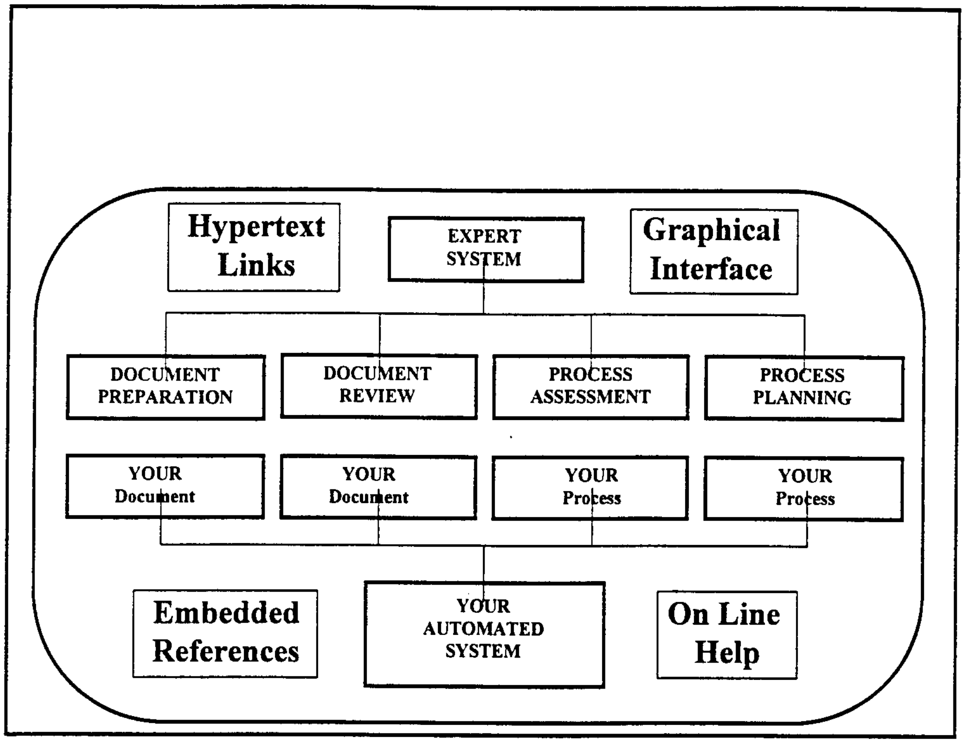

Figure 1 Automated Test Planning System (ATPS) Overview

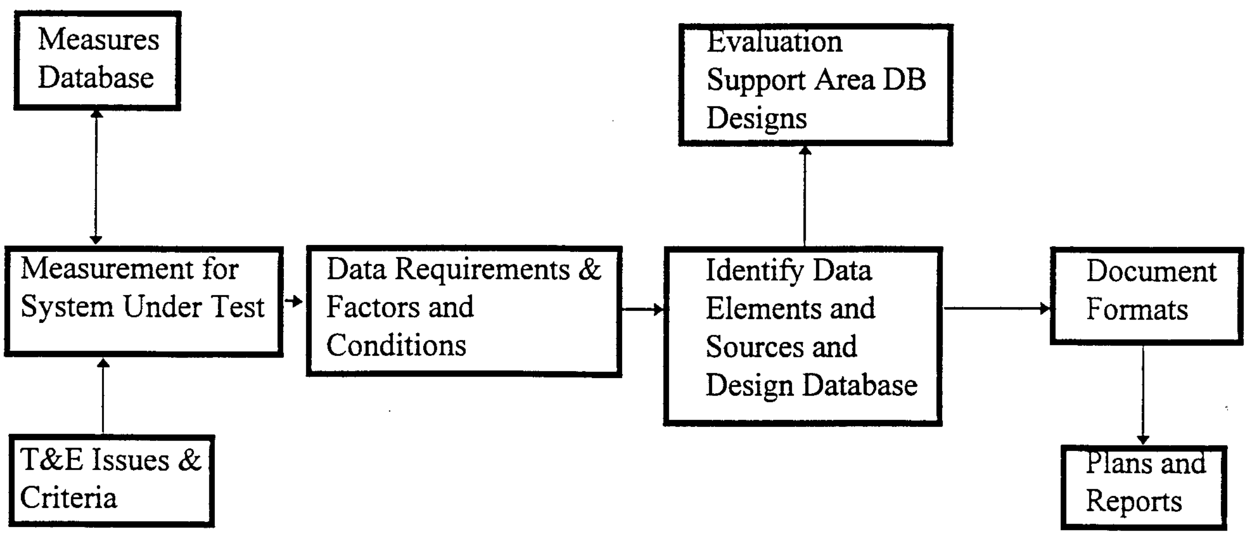

Figure 2 Test and Evaluation Planning and Reporting System (TEPRS) Overview

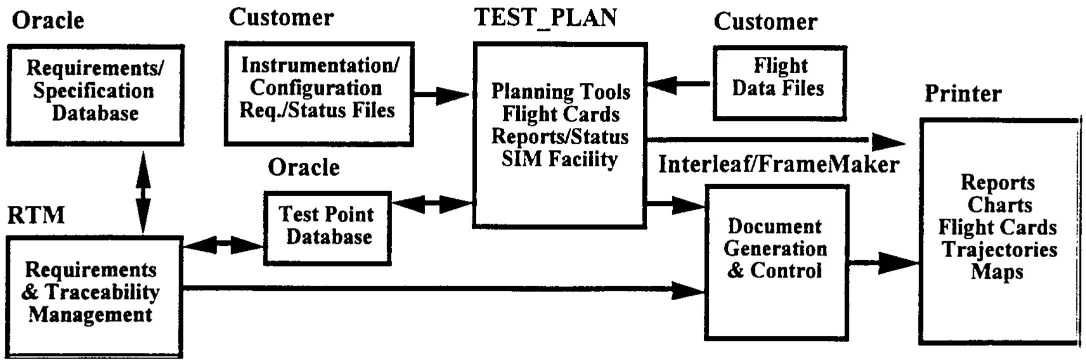

Figure 3 TEST_PLAN Flight Test Planning Functionality

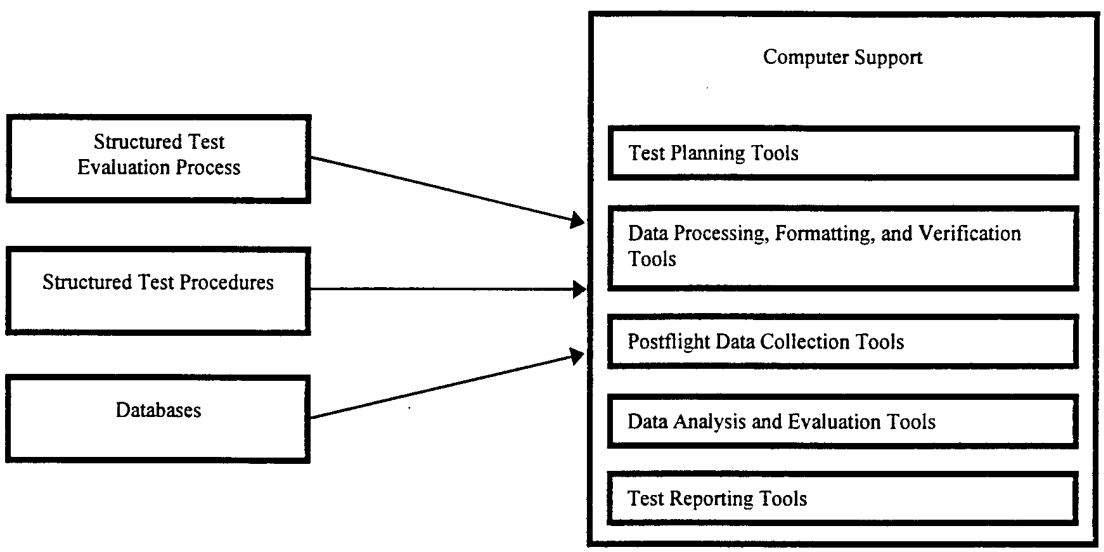

Figure 4 Test Planning, Analysis, and Evaluation System (PAES) Components

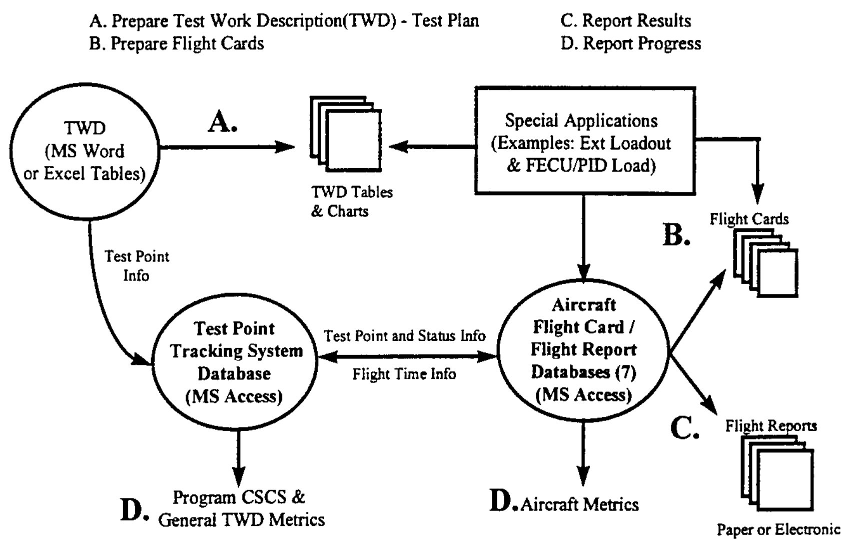

Figure 5 Planning and Reporting Organizer For Test Engineers (PROFTE) Overview

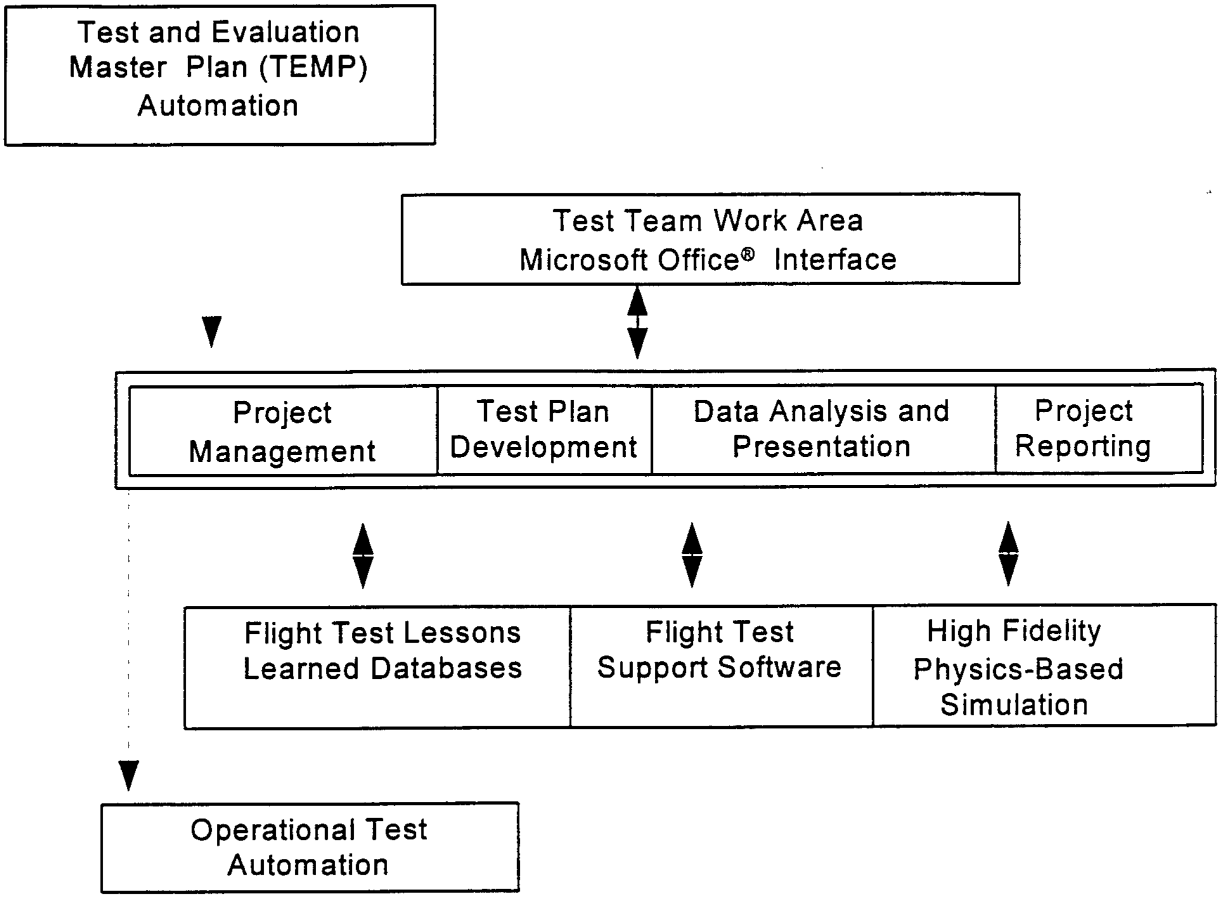

Figure 6 Automated Flight Test Engineering System (AFTES) Overview

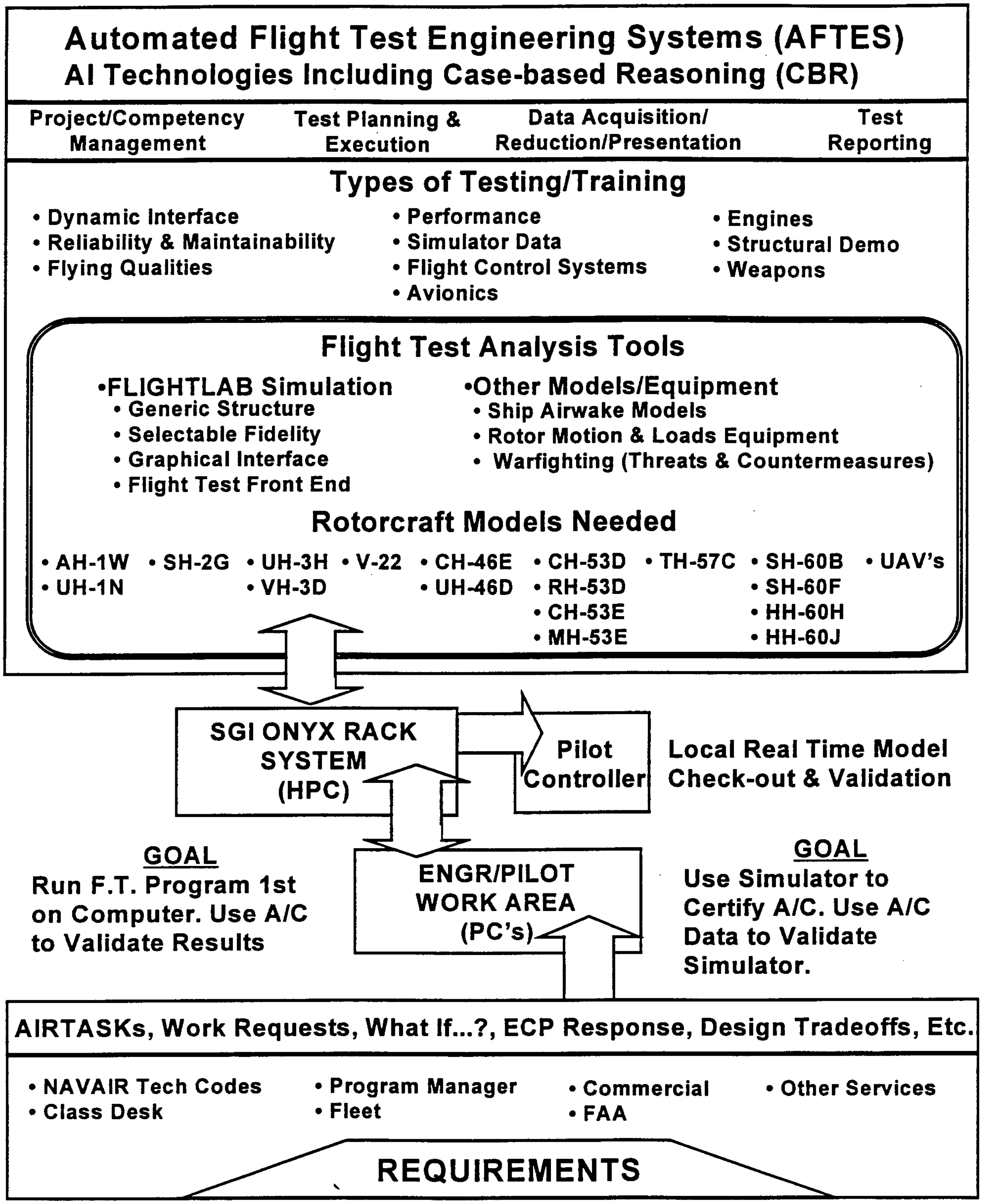

Figure 7 Rotorcraft Flight Test Automation Summary